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Height Growth to Age 8 of Larch Species and Hybrids in Wisconsin

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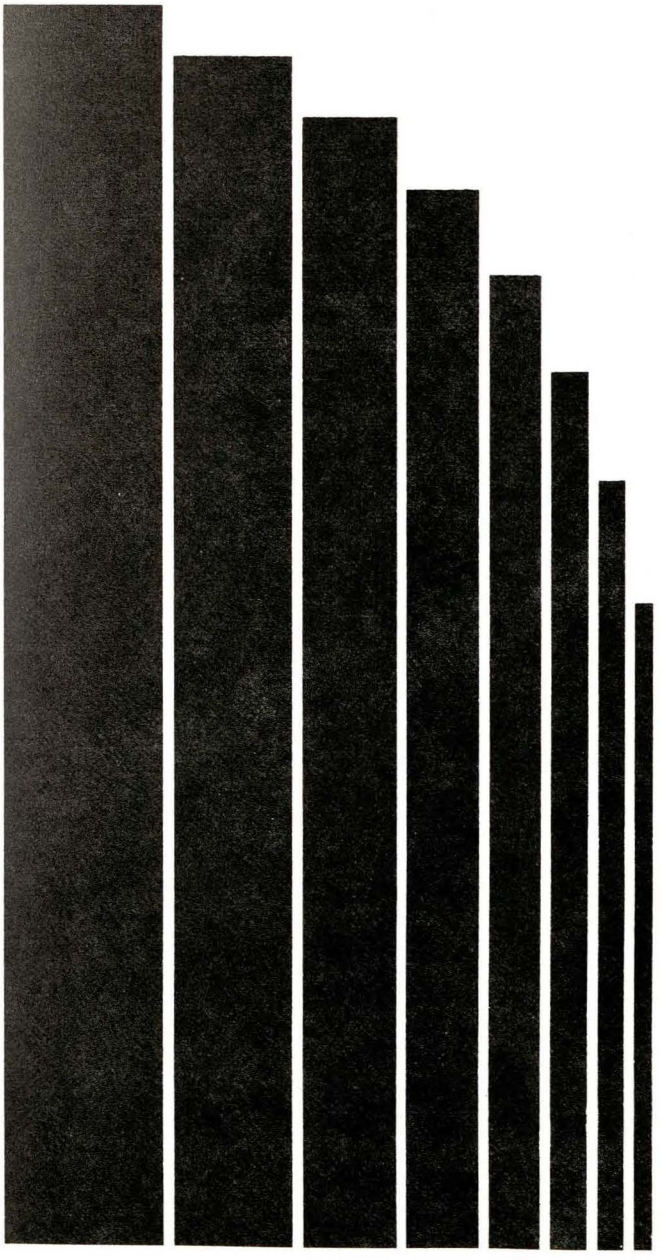

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Height growth of tamarack; Siberian, European and Japanese larch; and hybrids between the European and Japanese larch were compared in an 8-year-old test in north-central Wisconsin. Hybrids were tallest and the best reached 469 cm (15.4 feet) in mean height at age 8 years from seed. Hybrids exceeded European larch mean height by 12 percent and tamarack by 23 percent. Breeding strategies are discussed.

KEY WORDS: Progeny tests, provenances, breeding strategies, adaptation.

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HEIGHT GROWTH TO AGE 8 OF LARCH SPECIES AND HYBRIDS IN WISCONSIN

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European larch (*Larix decidua* Mill) and Japanese larch (*Larix leptolepis* [Sieb and Zucc] Gard.) have been tested on a limited scale in the North-central States and have demonstrated exceptional early growth. This good performance has stimulated an increasing interest in their management as a fiber crop using shortened rotations and intensive cultural practices (Jeffers and Isebrands 1974). Anticipating this development, we began a test of some of the best materials we could obtain from cooperators in Europe, Canada, and the United States in 1973. Hybrids between the two species as well as the native tamarack (*Larix laricina* (Du Roi) K. Koch) were included. This paper discusses height growth of the collections through 8 years of growth from seed.

PERFORMANCE IN OLDER TEST IN THE UNITED STATES

The good growth has occurred over a wide region. In Michigan, for example, heights of more than 7 m (24 feet) were reached at age 11 for one good European larch seed source from Schlitz, Germany (Barnes 1970). In northern Wisconsin 14 selected trees representing 5 provenances at 25 years from seed averaged 15 m (53 feet) in height and 20 cm (8 inches) d.b.h. (Jeffers and Isebrands 1974). On a more productive site in southwestern Wisconsin a 19-year-old plantation of European larch outperformed two native conifers (table 1), and at 12 years European larch was taller than any other species planted in western Iowa plots (Erdmann 1966). In Maine 27-year-old European larch grew an average of 62 cm (2.04 feet) per year compared to 43 cm (1.40 feet) for white pine (age 30) and 43 cm (1.40 feet) for white spruce (age 27) (Young 1957).

Japanese larch has also performed well. In Michigan, the best seed source produced 7 m trees 10 years after planting and large differences were noted among provenances (Lee 1976). On an adverse site in New York (Cook and Smith 1964) it was the one species that exceeded 9 m (30 feet) 21 years after planting. In Minnesota, at 24 years of age it had grown faster than any of the native conifers of similar ages in adjacent plots (Schantz-Hansen and Hall 1952), but at 45 years of age it had been surpassed by tamarack; red, jack, and white pine; and white spruce (Alm *et al.* 1972).

The hybrid between the two species is generally superior to the parent species. This has been the experience in many tests in Europe. In a typical example the hybrid produced 186 percent (239 m^3 per ha (3,416 cubic feet per acre)) and 168 percent (123 m^3 per ha[1] (1,758 cubic feet per acre)) of the volume produced by the Japanese (135 m^3 per ha (1,929 cubic feet per acre)) and European (73 m^3 per ha[1] (1,089 cubic feet per acre)) standards, respectively (Keiding 1980).

One 25-year-old study in New York compared "Dunkeld" larch with plots of European and Japanese larch. The best hybrid plot produced 162 percent of the volume in the best European larch plot and 110 percent of the volume in the best Japanese larch plot. The hybrid is resistant to larch canker (*Lachnellula willkommii)—a* serious pest on larch in Europe that recently has been reported on tamarack in New Brunswick, Nova Scotia, and Maine (Magasi and Pond 1982, Miller-Weeks n.d.) and on European larch in New England (Hepting 1971). It is resistant to needlecast disease *Mycosphaerella* sp. that has damaged some provenances of European larch in Iowa

[1]*These low volumes per hectare were the result of unusually heavy thinning.*

Table 1.—*Comparison of growth among European larch, white pine, and red pine on a productive site in southwestern Wisconsin*[1]

Growth measurement	European larch	White pine	Red pine
D.b.h. (cm)	17 (6.7 in.)	16 (6.3 in.)	15 (5.8 in.)
Height (m)	16.5 (54 ft)	12.0 (39 ft)	10.7 (35 ft)
Basal area (m^2/ha)	29.6 (129 ft^2/A)	29.8 (130 ft^2/A)	34.0 (148 ft^2/A)
Volume (m^3/ha)	189 (2,700 ft^3/A)	143 (2,050 ft^3/A)	147 (2,100 ft^3/A)

[1]Data compiled by Rod Jacobs, U.S. Department of Agriculture, Forest Service, North Central Forest Experiment Station, St. Paul, MN.

and southern Wisconsin, and it is not damaged by woolly aphids (*Adelges strobilobius)* (Shafer 1981). The hybrid survives better than the parent species on dry sites (Keiding 1980, Reck 1977).

MATERIALS AND METHODS

We included 37 seedlots in the test. Five seedlots of European larch were open-pollinated collections from selected trees in a 25-year-old stand of European larch at the Argonne Experimental Forest, Hiles, Wisconsin. One collection was made from a Siberian larch in the same stand and probably contained seed of European-Siberian hybrid origin. Four additional lots of European larch were obtained—one each from orchards in Denmark, Germany, Poland, and Canada.

Of the four Japanese larch seedlots, one was from a natural stand collection from Honshu, Japan; one from a Hokkaido, Japan, source received through Denmark; one was from an orchard in East Germany; and one was from a seed orchard of selected trees in Hokkaido, Japan.

Seedlots of *Larix eurolepis* (European x Japanese) were obtained from orchards in Denmark. Two of these hybrid lots involved crosses between selected clones of European larch of Alps origin (females) and selected Japanese larch clones (males). A third hybrid seedlot originated from an orchard consisting of a single selected European clone from Zagnansk, Poland, and several selected Japanese clones. One seedlot of the reciprocal cross (Japanese x European) was obtained from a clonal orchard in Sweden containing one clone of Japanese larch and 10 selected clones of European larch. The origin of the European clones were unknown but probably Scottish.

In addition of known hybrid seedlots, 13 seedlots were obtained from multi-clonal orchards in Scotland and Denmark containing a mixture of European and Japanese clones. Five lots from Scotland were open-pollinated collections from Japanese larch clones and were probably a mixture of Japanese x Japanese and Japanese x European. Three lots from Scotland and five lots from Denmark were open-pollinated collections from European larch and were a mixture of European x European and European x Japanese. The Danish orchard is made up of clones of selected inbreds of the two species. Two additional seedlots of European larch x mixture of European and Japanese larch were obtained from East Germany.

Four open-pollinated single tree collections of tamarack (*Larix laricina*) from Ontario were also included in the study.

Seed was sown in April 1973. Seedlings were grown in plastic tubes in a 1:3:1 sand, peat, perlite growing media in the greenhouse until June. A 20-hour photoperiod and constant 72°F temperature was maintained throughout this phase. Seedlings were transferred to a shadehouse on June 11 and grown under a 20-hour photoperiod and normal outdoor temperatures. The seedlings were transplanted to the Hugo Sauer Nursery at Rhinelander, Wisconsin, in a randomized complete block design in August 1973.

In April 1976 the seedlings were field planted on a sandy loam site at the Harshaw Experimental area, Oneida County, Wisconsin. The previous summer the site was prepared by plowing, disking, and strip-treating with herbicide. The experimental design was randomized complete blocks with 10 replications and 4-tree plots. Because the 3-year-old seedlings were very large (60-150 cm (2 feet–5 feet) tall) and much of their root systems were lost during lifting, most

of them were pruned shortly after planting. We removed all of the 1975 terminal shoots from the large seedlings and up to 1-1/2 of the 1975 terminal shoots from the smaller seedlings. Some of the lateral shoots were also removed from the largest seedlings. In the spring of 1977, dead trees were replaced where stock was available.

All trees were measured for total height in 1977 after five growing seasons and again in the fall of 1980 after the trees were 8-years-old from seed. The two height measurements and the 5-year to 8-year increment were analyzed via analysis of variance. Differences between species and hybrids were tested using single degree of freedom comparisons, and the three groups of seedlots from multiclonal orchards (13 lots total) were compared in a separate test.

RESULTS

Mean height for all trees in the test was 410.8 cm (13.5 feet) in the fall of 1980. This represented a mean yearly height growth of more than 51 cm (1.7 feet) from seed. The 5-year to 8-year increment was 218.9 cm (7.2 feet)—much more than half of the total, for a mean yearly growth of almost 73 cm (2.4 feet) for the 3-year-period (table 2). Differences between seedlots were significant for both height measurements and the 5-year to 8-year increment (table 3). Likewise, the mean performance of the hybrids was consistently greater than that of the parent species (table 2, fig. 1).

After 5 years of growth, no differences were found between European larch (mean height 184.9 cm (6.1 feet)) and Japanese larch (mean height 184.8 cm (6.1 feet). During the next 3 years, however, the European larch grew an average of 234.1 cm (7.7 feet) while the Japanese larch grew an average of only 185.3 cm (6.1 feet). Japanese larch had the poorest 5-year to 8-year increment of any group in the test. After 8 years the Japanese larch was only 88 percent as tall as the European larch, and ranked last (table 2, fig. 1).

At 5 years the hybrids ranked 1 and 2 in total height at 216.5 cm (7.1 feet) for European x Japanese and 209.1 cm (6.9 feet) for Japanese x European (table 2). After 8 years, the ranking remained the same. European x Japanese seedlots averaged 469.4 cm (15.4 feet) in total height or 114 percent of the plantation mean while Japanese x European hybrids averaged 448.4 cm (14.7 feet) or 109 percent of the

Table 2.—*Mean heights at 5 and 8 years and 5-year to 8-year height increment of larch seedlots grouped by parentage*

Group	Seedlots	5-year height		Rank	5-year to 8-year increment		Rank	8-year height		Rank
	No.	cm	ft		cm	ft		cm	ft	
Siberian larch	1	182.9	(6.0)	8	248.0	(8.1)	2	430.9	(14.1)	3
European larch	9	184.9	(6.1)	6	234.1	(7.7)	4	419.0	(13.7)	4
Japanese larch	4	184.8	(6.1)	7	185.3	(6.1)	8	370.1	(12.1)	8
European x Japanese	3	216.5	(7.1)	1	252.9	(8.3)	1	469.4	(15.4)	1
Japanese x European	1	209.1	(6.9)	2	239.3	(7.9)	3	448.4	(14.7)	2
Japanese x mixture of Japanese and European	5	190.1	(6.2)	5	203.6	(6.7)	6	393.6	(12.9)	6
European x mixture of Japanese and European	10	193.1	(6.3)	3	224.0	(7.3)	5	417.2	(13.7)	5
Tamarack	4	193.1	(6.3)	3	187.2	(6.1)	7	380.3	(12.5)	7

Table 3.—*Analyses of variance of 5-year and 8-year height and 5-year to 8-year increment of larch seedlots*

Source	df	5-year height		5-8 year increment		8-year height	
		MS	F	MS	F	MS	F
Reps	9	3,720	4.32**[3]	2,822	3.32**	12,205	4.48*
Seedlots	36	4,238	4.92**	8,576	10.08**	20,621	7.58*
Parent groups	7	4,104	4.77**	23,955	28.15**	35,664	13.10*
Hybrids vs parent species	1	27,128	31.51**	28,297	33.25**	110,838	40.72*
European vs Japanese	1	0	0NS[5]	65,947	77.49**	66,218	24.33*
E x J vs J x E	1	411	.48NS	1,387	1.63NS	3,307	1.21N
JM[1] vs EM[2]	1	320	.37NS	13,872	16.30**	13,333	4.81*[4]
Error	324	861		851		2,772	

[1]JM = Japanese larch x a mixture of Japanese and European larch.
[2]EM = European larch x a mixture of Japanese and European larch.
[3]** = signififcant at $P > 0.99$.
[4]* = significant at $0.99 > P > 0.95$.
[5]NS = not significant.

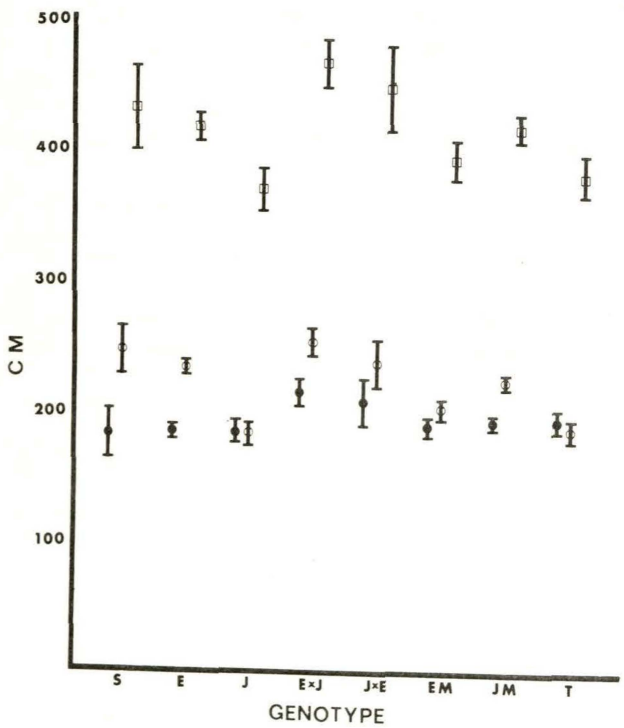

Figure 1.—*Mean height at 5 years (●), 8 years (□), and the 5- to 8-year increment (○) for Siberian (S), European (E), Japanese (J), European x Japanese (E x J), Japanese x European (J x E), European x a mixture of Japanese and European (EM), Japanese x a mixture of Japanese and European (JM) larches and tamarack (T). Confidence intervals are 2 times the standard error of the mean.*

plantation mean. No statistically significant differences were found in total height or increment between the two hybrid groups.

The Siberian larch had the lowest 5-year height of all groups in the test (182.9 cm (6.0 feet)). However, between 5 and 8 years of age, this seedlot grew 248.0 cm (8.1 feet) ranking second only to the European x Japanese larch hybrid (252.9 cm (8.3 feet)). At 8 years of age, the Siberian larch was 430.9 cm (14.1 feet) tall and ranked behind both hybrids. Increasingly good performance may indicate a substantial percentage of natural Siberian x European larch hybrids in the seedlot.

Height of seedlots derived from multiclonal orchards was not as great as that of the all-hybrid groups and tended, at all ages, to be intermediate between the parents and the hybrids. By age 8 the two multiclonal groups ranked 5th and 6th, above only Japanese larch and tamarack (table 2, fig. 1). However, the 10 seedlots of the European x mixture of Japanese and European clones (417.2 cm (13.7 feet) height at age 8) gave different results depending on origin. The five Danish lots were the poorest (389.0 cm (12.8 feet) at age 8), and the Scottish sources were second poorest (436.6 cm (14.3 feet)). The two lots from East Germany averaged 458.5 cm (15.0 feet) and were similar to all-hybrid collections. The differences among the three groups were highly significant ($F = 9.99$).

DISCUSSION

The results substantiate the often reported superiority of the first generation hybrid between European and Japanese larch. The magnitude of the

superiority over European larch—469.4 cm (15.4 feet) vs. 419.0 cm (13.7 feet) or 12 percent—is low compared to other experiments, which have reported up to 49 percent superiority. At age 8 in our study the hybrid was 23 percent taller than tamarack on the average.

Pure European larch also performed well; on average, the populations exceeded tamarack by 10 percent. The two best sources were from single tree collections made in a provenance test growing near Rhinelander. One represented a provenance mix from the Austrian Alps (600-1,200 m (2,000 feet–4,000 feet)) the other a mix of low elevation German collections of which several were from plantations. The best provenance collection was from Blizyn, Poland. These three collections were from 19 to 22 percent taller than tamarack collections.

The poor performance of Japanese larch in this study is not unique. Farnsworth *et al.* (1972) mentioned an example in which "heavy (spring) frosts in successive years were partially responsible for the rapid decline of two Michigan plantations located in frost pockets". They also mentioned dieback from winter cold in the nursery. With one exception the trees became hardier as they grew older. But in a Wisconsin test of 22 provenances, some seed sources showed heavy damage and others light damage several years after planting. The severity of spring as well as winter damage was correlated with differences among mountains of origin.

The best seed source in our test was from a seed orchard on Hokkaido—the northernmost Japanese island. Natural populations of larch occur on the Japanese island of Honshu, between approximately 35° and 37°N. Hokkaido is located between approximately 42° to 45°N; day-length there is closer to that in Wisconsin and, with the exception of the coastal regions, the climate is colder than it is within the native range. Farnsworth *et al.* (1972) reported significant variation in the degree of damage from both spring frosts and winter cold. The results suggests that selection in Hokkaido plantations in a colder environment has resulted in a population pre-adapted to the cold Wisconsin environment as well. Considering the variation observed in the North Central States (Farnsworth *et al.* 1972), our results with the Hokkaido selection suggest that breeding of the best trees from the best adapted provenances may yield better adapted trees. The better performance of the multi-clonal seedlots developed in the more continental climate in East Germany may point in the same direction.

Tree breeders have several options for breeding *Larix* in the north-central region. Together with previously published information our results substantiate that volume production can be improved in a single generation by hybridizing European and Japanese larch. Another gain from hybridizing is the introduction of pest resistance mentioned earlier.

A multigeneration hybrid breeding program is a more complex proposition. Two avenues are available to improvement: (1) developing a new population (equivalent to a new species or race) using hybrids as the breeding stock; (2) breeding the individual parent species using a recurrent selection scheme. The hybrids would be produced from the improved products of breeding of the two species.

With our current knowledge of *Larix* genetics, particularly as it relates to the adaptation to the harsh environment in the north-central region, and with the *Larix* materials now available, it is not possible to determine which option will be most effective. Lester (1975) has discussed the problems that may complicate advanced breeding of hybrids as considered under option 1. He listed the following factors as those that could restrict access to desired gene combinations: nonrandom assortment of genes at meiosis, pleiotropy, nonrandom elimination of gametes or genotypes, sterility in the F_1 hybrids, and hybrid breakdown in the F_2. Available information on the performance of the parent species and F_1 hybrids is not sufficient to determine the impact of these factors. However, we have observed no sterility problems in the F_1.

Hyun (1974) has described the performance of a hybrid F_2 pine of a combination in which one parent species was not climatically adapted. Under more severe conditions, the F_2 did not perform as well as the F_1. He suggested that in the F_2 generation individuals segregating in the direction of the nonadapted parent suffer cold damage.

Our results show on the one hand that our Japanese larch collections are poorly adapted to the test site, and on the other hand that hybrid superiority is low compared to results elsewhere. The hybrids were developed in western Europe in milder climates; perhaps the hybrids would have performed better if the Japanese larch parents had been selected in our continental climate. If this assumption is correct, the available hybrids do not represent the best parent breeding stock. Option 2 will then become an important first step. Recurrent selection for improved growth in both parent species would pro-

vide breeding material for producing improved pure species stock and improved hybrids. The initial choice of within-species improvement would not preclude later breeding within hybrid populations. At any generation the breeder should have the flexibility to pursue either intra-specific or inter-specific breeding. Because additional research is needed before the efficiency of alternative breeding systems can be determined, it will be very important to maintain as many breeding options as possible.

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